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RESEARCH ARTICLE

# Seasonality in Grey Wolf prey selection in the Northern part in the Central Balkan Mountains (Bulgaria)

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## Abstract

The main prey of the Grey Wolf (*Canis lupus* L.) in the Central Balkan Mountains are wild and domestic ungulates. It was established that the carnivore employed a seasonal selectivity in its prey that was established by analysing Wolf's excrements collected in 2018–2020. In winter, the diet included exclusively wild animals, with a differing share of prey species. The biggest share belonged to Red Deer (56.8%). In spring (when the grazing of domestic animals begins), the highest share was to Horses (juveniles) (52.1%), and from the wild animals to Roe Deer (18.8%). During the summer, juvenile Horses again constituted the biggest part of the diet (47.2%), as well as Roe Deer (20.8%). In autumn, juvenile Horses again predominated, with Wild Boar was at second position (15.6%). Ivlev's selectivity index was used to determine Wolf prey preference (*D*). In respect of Red Deer, Wolves exhibit positive selection of $D = 0.30$ for frequency of occurrence in excrements, and of $D = 0.21$ for biomass. Conversely, Roe Deer are negatively selected during the winter: $D = -0.44$ for occurrence, and $D = -0.45$ for biomass. In the warmer part of the year, the Wolf showed positive selection towards Roe Deer ($D = 0.40$), and negative selection for Wild Boar ($D = -0.64$ for biomass). From domestic animals, there was strong selection for juvenile Horses in respect of both indexes. Frequency of occurrence is $D = 0.98$, while use of biomass is $D = 0.97$. Livestock shows negative selection for both indexes ($D = -0.38$) and (-0.31). Sheep occur least of all in the predator's diet, the coefficient for both indexes strongly showing negative selection ($D = -0.94$).

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**Keywords**
Central Balkan Mountains, *Canis lupus*, occurrence of prey, biomass, livestock, victims, wild ungulate.

## Introduction

The Grey Wolf (*Canis lupus* L.) is the European most active hypercarnivore. It is a natural regulator of herbivores' number, helping to maintain the ecological balance and keeping prey populations healthy in ecosystems, of which they are a part (Mech, Peterson 2003), a role that is difficult for game managers to replace. Attitudes towards the Wolf populations are contradictory due to the losses inflicted on hunting resources and livestock, and to the opinion for its negative impact on human livelihoods (Filonov, Kaletskaya 1985). The species is present in 34 countries, including the Russian Federation, where the biggest numbers is distributed (Boitani et al. 2022). In the last decades, the Wolf has shown a remarkable capacity to take advantage of opportunities for reoccupying large areas of its former continental habitats. Due to increased conservation efforts, the number of Wolf's population is recovering. Attitudes towards the animal are contradictory, due to the losses inflicted on hunting resources and livestock.

In Bulgaria, *Canis lupus* has been included in the country's Red Book since 1985, and is categorised as a threatened species (Spiridonov and Spassov 1985, 2015). Currently, its population has reached the point of extinction by the end of the 1960s–'70s, due to banning the use of poisoned bait, as well as to growing of the numbers of wild ungulates. An expansion of the Wolf population began in the 1980s. Consequently, the Central Balkan Mts. was reoccupied in the first half of the 1980s, with the first killed Wolf on the northern part being recorded in 1987 (Spassov et al. 2000; R. Gunchev personal communication). By 1996, the Wolf was already present over the entire length of the Central Balkan Mts., nearly reaching the Black Sea coast (Spassov 2007).

In Bulgaria, there is insufficient knowledge about the ecology of the Grey Wolf, including the nutritional characteristics of the species. Studies on the diet of *C. lupus* were conducted only in the Western Rhodope Mts. (Georgiev et al. 2008; Serafimov et al. 2008; Genov et al. 2015), in Sredna Gora Mt. (Ivanov 1988), in Western Pirin and Kraishte Mts (Dutsov et al. 2015) and the Bulgarian part of Osogovo Mt. (Stancheva, 2004; Dolapchiev et al. 2022).

In the Central Balkan Mts., the diet of *C. lupus* has not been studied in details. It should be noted that this region is extremely interesting due to the presence of diverse habitats, including forest habitats and subalpine areas, managed in different ways. Two State Hunting Enterprises (SHE) (Rositsa and Rusalka) with a high concentration of ungulates are developing economic activity in the forest zone, and the subalpine zone is managed by the Central Balkan National Park.

The present study provides new data on the Grey Wolf ecology, and, more particularly, on the seasonal prey selection of the species.

## Materials and method

*Area of research and ungulate prey presence*

The forested territory of the Central Balkan Mts. includes a belt of xerothermic oak forests (600–700 m a.s.l.), xeromesophilic and mesophilic oak and hornbeam forests (700–900 m a.s.l.), beech forests 800–1600 m a.s.l.), coniferous forests (1600–1850 m a.s.l.), and a subalpine belt, which covers limited areas on the highest ridges and peaks (Botev, Vezhen, Ambaritsa, Triglav, etc.). Our survey was conducted on a total area of 784 km$^2$.

The tree communities in the lowest parts of the SHE Rositsa and Rusalka are represented mainly by oak forests, mainly by *Quercus cerris* L., *Q. frainetto* Ten. and *Q. pubescens* Willd., as well as *Q. dalechampii* Ten., *Carpinus betulus* L., *C. orientalis* Mill. and partly *Pinus nigra* Arn. In addition, *Salix* spp. and *Alnus* spp. are found along the river banks. In the middle and highest parts of the mountain, the *Fagus sylvatica* L. belt and the coniferous species represented by *Pinus sylvestris* L., *Abies alba* Mill. and *Picea abies* L. are characteristic. Among the shrubs, *Juniperus sibirica* Burgsd., *Vaccinium myrtillus* L. and *Bruckenthalia spiculifolia* (Salisb., Reichenb.) are found. The distribution of *Pinus mugo* Turra, *Arctostaphylos uva-ursi* L., *Rubus ursinus* Cham., Schltdl. and *R. idaeus* Cham., Schltdl. is more limited.

The Subalpine zone of the Central Balkan National Park provides excellent opportunities for grazing of domestic livestock during a large part of the growing season, in the absence of noticeable human activities, providing peace to *C. lupus*, especially during the breeding season.

The wild ungulates common for the Central Balkan Mts. are Red Deer (*Cervus elaphus* L.), Roe Deer (*Capreolus capreolus* L.), Mountain Goat (*Rupicapra rupicapra* L.), and Wild Boar (*Sus scrofa* L.). At the beginning of the 1930s, the Red Deer had disappeared from these areas (Spassov et al. 2000). At present, it is commonly met both in hunting areas, and in the wooded parts of the Central Balkan National Park at all altitudes. During the rut period, it is met in the subalpine belt. Roe Deer is also met at all altitudes. On the northern slopes of the Central Balkan National Park, Wild Boars cover considerable distances in their search for food.

The research area of present study included the territory of SHE Rusalka and Rositsa, as well as the hunting areas of Cherni Osam and Todorchetata, belonging to them (Fig. 1).

Snow cover keeps for 4–5 months at altitude 1000–1500 m. On northern slopes at 500–800 m above sea level, the average monthly thickness of the snow cover is around 25–30 cm. Higher up in the mountain it often reaches 1 m or more (Central Balkan National Park Management Plan, 2016–2025).

*Excrements*

A widely used method for determining carnivore diet is excrements analysis. It allows identification of prey species on the basis of teeth, bones, feathers, and the coticule scale and medullary characteristics of hairs found in excrements (Spaulding et al.

2001). Wolf excrements have been collected throughout the year in 2018–2020. The whole research area has been surveyed for a total of 75 days, mainly along forest roads and paths regularly used by the carnivore 200 securely identified excrements have been collected (Fig. 1).

The distinction between Wolf and Dog excrements is made according to Spassov (2007). The classification of the samples by season was carried out by estimating the time elapsed from the time they were left until they were found. Hairs from prey were identified by microscopic observation (NU 2, magnification of 125 and 156 times). The hairs found in excrements was identified by using the atlases of Debrot et al. (1982), and Teerink (2003), as well as by comparing with hairs from wild and domesticated animals typical for the area of research.

Laboratory procedures were based on the principles presented by Reynolds and Aebischer (1991), Ciucci et al. (1996). After sterilisation, the samples were soaked for 24–48 hours in water at room temperature, with the addition of a few drops of detergent to aid in disintegration. They were broken and washed through a sieve with a whole diameter of 0.2 cm. This achieved the removal of microcomponents and soluble particles, leaving only macrocomponents for analysis. The contents of the sieve were poured onto a white sheet of paper and left at room temperature until

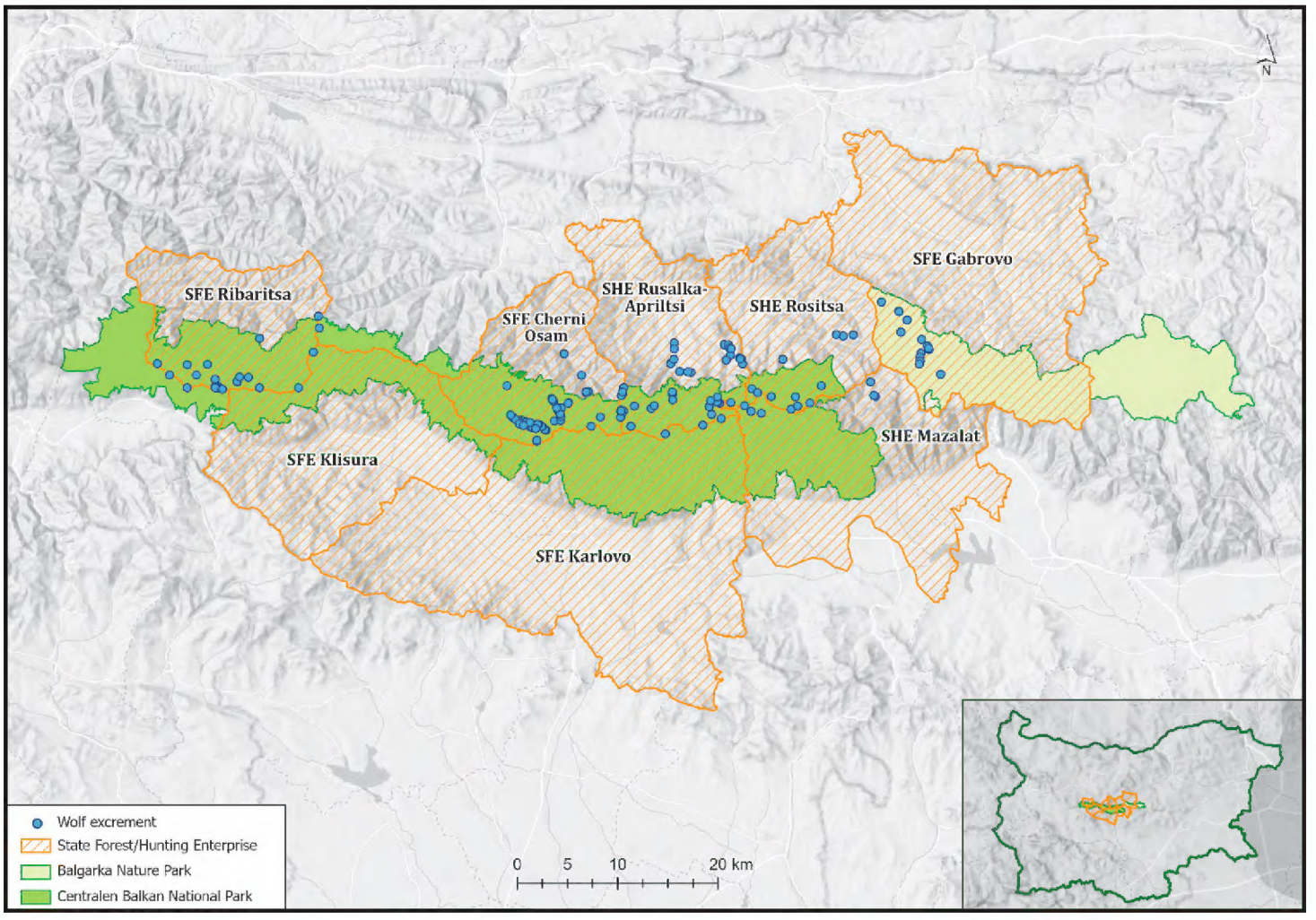



**Figure 1.** Area of research in the northern parts of the Central Balkan Mts. and the administrative units included in it.

they reached an air-dry state. To determine biomass, individual categories were weighed to the nearest 0.01 g.

When dividing the prepared samples to determine the remains of the ingested prey, following the standard methodology, it was found that the samples contained additional (non-food) digested components. When weighing, this gave inflated results, including higher values in the calculation formula and led to an overestimation of the digested biomass. To avoid this error, an additional step to the established method was adopted: absolutely dry samples were rubbed through a larger sieve (0.5 cm), to separate and free from non-food and completely digested components in the fur. With the help of tweezers, all components that make up the food of the predator were collected - hair, bones, teeth, hooves and tendons from its victims, as well as plant food that was purposefully ingested.

With the occurrence method, it is possible that several samples contain remains of the same animal, when several Wolves have fed on one victim or, in the case of large victims, several times.

The analysis of the samples was carried out according to the two standard methods - frequency of occurrence and consumed biomass. The first method provides reliable information about the relative participation of individual prey types in the Wolf's overall food complex, and the second - about the amount of biomass consumed, respectively the number of prey.

The frequency of occurrence is the ratio of the food (prey species) to the total number of samples, expressed as a percentage (Voigt et al. 1976). Species occurring in minor quantities (up to 1%) in the samples are not included in the occurrence method.

Consumed biomass was determined based on established relationships between the amount of food eaten by predators and the excrements deposited afterwards using a linear regression model. It was obtained by experimentally feeding wolves under artificial conditions (Weaver 1993). The dependent variable 'y', ($y = 0.439 + 0.008 x$; $r2 = 0.78$) represents the ingested biomass for each scat sample, while the independent variable 'x' is the live weight (kg) of prey ingested in the samples. The occurrence method gives an advantage to large prey, because a family of Wolves, feeding on such prey and moving together, the several excrement samples they leave behind later are from the same animal. Conversely, the biomass method gives an advantage to small animals, because the predator cannot use the massive bones of large prey for food, while it uses them from smaller ones. When measuring the weight of the remains in the excrement, those with more bones (Roe Deer) are heavier than those with only fur (Red Deer).

The average live weight of the victims was taken from literature data for European conditions as follows: *Cervus elaphus* – 69 kg (Jędrzejewski et al. 2000); *Sus scrofa* – 45 kg (offspring 10 kg) (Ansorge et al. 2006), *Capreolus capreolus* – 18 kg (offspring 4 kg) (Glowacinski 1997; Ansorge et al. 2006). For livestock (Cow, *Bos taurus* L. and Horse, *Equus ferus caballus* L.) Georgiev et al. (2008) assumes 20 kg, however, from the remains found in the area during the field research, it is understood that not only newborns become victims. For this reason, an average weight of at least 80 kg (Cow

and Horse) and 55 kg for Sheep (*Ovis aries* L.) was adopted (personal communication with shepherds).

Advantages and disadvantages are observed in both methods, however, applied together, they reveal in more detail the nutritional characteristics of the Wolf, in contrast to the stomach contents, where it is possible that the stomach was empty at the time of shooting.

*Numbers of the prey species*

The number of wild ungulates used as prey has been presented according to data from official taxation, provided by the Executive Forests Agency (Table 1), made in hunting farms. The indicated number of individuals also includes the animals from the National Park, since the area of habitat of the indicated species also includes the park. The numbers and the domestic animals (Table 2) comes from official data of the Central Balkan Park Management.

*Prey selectivity (Ivlev's selectivity index to determine Wolf preference for its prey)*

Prey selectivity in respect of wild ungulates is presented by using Ivlev's selectivity index (*D*) (Ivlev 1962), partly amended by Jacobs (1974). The index addresses frequency of occurrence of food residue in Wolf excrements, as well as the consumed biomass.

$$D = \frac{r - p}{r + p - 2rp}$$

*r* – gives the relative presence of prey occurring in the samples, and is estimated separately for each respective biomass (Table 3) and for frequency of occurrence (Table 4).

*p* – relative share of prey species in the community of ungulates.

The values of *p* have been estimated as percentage of the presence of each type in the ungulate community, according to the last taxation (spring count) for this area. Ivlev's selectivity index fluctuates between -1 (negative prey selection), and 0 (selection proportional to frequency of occurrence), to 1 (maximum positive selection) (Jacobs 1974). We consider the value of *p* to be the same for the entire territory because the

**Table 1.** Numbers of game species in Rusalka and Rositsa State Hunting Farms for 2018-2020 after the official taxation data and their percentage ratio for the survey period

| Species | Red Deer | Roe Deer | Wild Boar |
|---|---|---|---|
| 2018 | 1531 | 1824 | 1530 |
| 2019 | 1613 | 1912 | 1705 |
| 2020 | 1335 | 1648 | 573 |
| Average | 1493 | 1795 | 1269 |
| *p* | 0.33 | 0.39 | 0.28 |

**Table 2.** Numbers of livestock in Central Balkan National Park and their percentage ratio for the survey period

| Domestic animals | Sheep | Cattle | Horses |
|---|---|---|---|
| 2018 | 15554 | 6473 | 1076 |
| 2019 | 15529 | 7802 | 831 |
| 2020 | 14745 | 7161 | 925 |
| Average | 15276 | 7145 | 944 |
| *p* | 0.65 | 0.31 | 0.04 |

indicated number of individuals also includes the animals from the National Park, since the area of habitat of the indicated species also includes the park.

Wild prey abundance based on the relative prey presence (r) was additionally tested for each of the variables occurrence and biomass by seasons applying one-way analysis of variance, which was preceded by arcsin sqrt transformation for

**Table 3.** Biomass of prey species found in excrements

| Species | Winter | Spring | Summer | Autumn | Sum | *r* (entire annual period) | *r* (cold period) | *r* (warm period) |
|---|---|---|---|---|---|---|---|---|
| Red Deer | 18053.03 | 7772.13 | 7088.50 | 2715.38 | 35629.03 | 0.37 | 0.43 | 0.32 |
| Roe Deer | 5962.13 | 11362.38 | 16957.89 | 3713.13 | 37995.51 | 0.40 | 0.20 | 0.60 |
| Wild Boar | 10854.58 | 1439.13 | 2220.50 | 7183.38 | 21697.58 | 0.23 | 0.37 | 0.08 |

proportions. When significant, Tukey's post-hoc test was applied to distinguish the statistically significant groups of means (Sheskin, 2004).

The required average daily amount of food for one Wolf is about 3.0 kg (Ivanov, 1988), therefore, the annual need for meat for one animal is 1095.0 kg. In the study

**Table 4.** Occurrence of prey species in excrements during the four seasons, for the warm season, for the cold season, and in sum

| Species | Winter | Spring | Summer | Autumn | Sum | *r* (entire annual period) | *r* (cold period) | *r* (warm period) |
|---|---|---|---|---|---|---|---|---|
| Red Deer | 25 | 7 | 8 | 3 | 43 | 0.43 | 0.47 | 0.36 |
| Roe Deer | 7 | 9 | 11 | 5 | 32 | 0.32 | 0.20 | 0.48 |
| Wild Boar | 12 | 3 | 4 | 7 | 26 | 0.26 | 0.32 | 0.17 |

area the density of the Wolf population 0.03 individuals/ km$^2$ was calculated using the camera trap method, according to Koychev et al. (2021). This means that 23 Wolves inhabit the studied area (784 km$^2$).

## Results

*Seasonality in the share of each prey in Wolf diet*

The seasonal distribution of samples (excrements) showed that 41 of them belong to winter food, 54 – to that of spring food, 59 – to that of summer food, and 46 – of autumn food. Seasonal differences in numbers were due to the varying degree of difficulties in finding relative to season.

The excrements analysis indicated that occurrence of domestic animals in spring, to a good degree during the summer, and most of all in the autumn, was higher than that of wild ungulates (Fig. 2). In winter, traces of domestic animals were not found, which is to be considered as due to the fact that they are kept in enclosures. The proportion between the two prey categories (wild and domestic) changes according to season (Table 5).

The biggest share in Wolf diet during the winter belongs to Red Deer, with Wild Boar coming second, and Roe Deer taking the third place. In spring, the biggest share falls to Horses (predominantly juveniles), with Roe Deer coming second, followed by Red Deer, Cattle, and Wild Boar. During the summer, ranking is the same: Horse, Roe Deer, Red Deer, Cattle, Wild Boar. During the autumn, the ranking is Horse, Wild Boar, Cattle, Roe Deer and Sheep, Red Deer (with the smallest share) (Fig. 2).

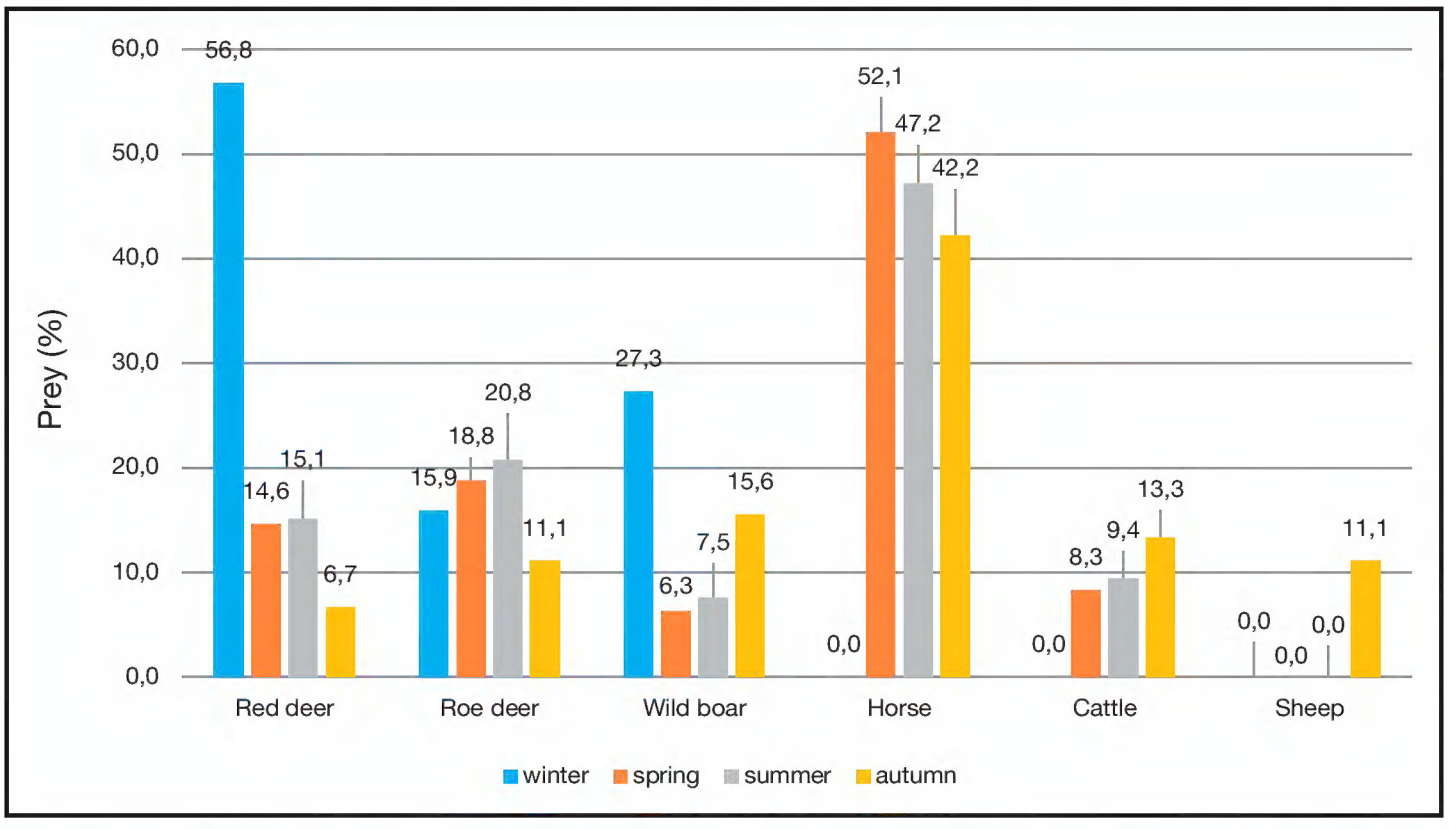



**Figure 2.** Percentages of wild and domestic prey types in Wolf excrements for each seasons.

**Table 5.** Percentage ratio between wild and domestic ungulates by season

| Prey | Winter | Spring | Summer | Autumn |
|---|---|---|---|---|
| Wild ungulate | 100 | 39.6 | 43.4 | 33.3 |
| Livestock | 0 | 64.4 | 56.6 | 66.7 |

For each one of the species, participation according to season is as follows. During the winter, the share of Red Deer is biggest compared to the rest of the seasons. The same is true for Wild Boar, while the share of Roe Deer is biggest during the summer. Horse is part of the diet principally during the summer, Cow – in autumn, while taking Sheep is exclusively during the autumn (Fig. 3).

The proportion of Red Deer according to occurrence was proven to be significantly higher than that of Roe Deer in winter, while the presence of Wild Boar in Wolf diet according to biomass outperformed significantly the other species in autumn. The observed ranking of the wild ungulates (Fig. 2) in the other seasons although well distinguished (Figures 4 and 5) was not significant due to variation between different years.

*Wolf's prey selectivity*

Values for Ivlev's selectivity coefficient which have been received do not indicate categorical pray preference. Nonetheless, in CBR wolves show positive selection towards Red Deer, both as regards occurrence ($D = 0.21$), and the consumed biomass ($D = 0.10$) (Fig. 6A). For Roe Deer negative or nearly zero values are observed

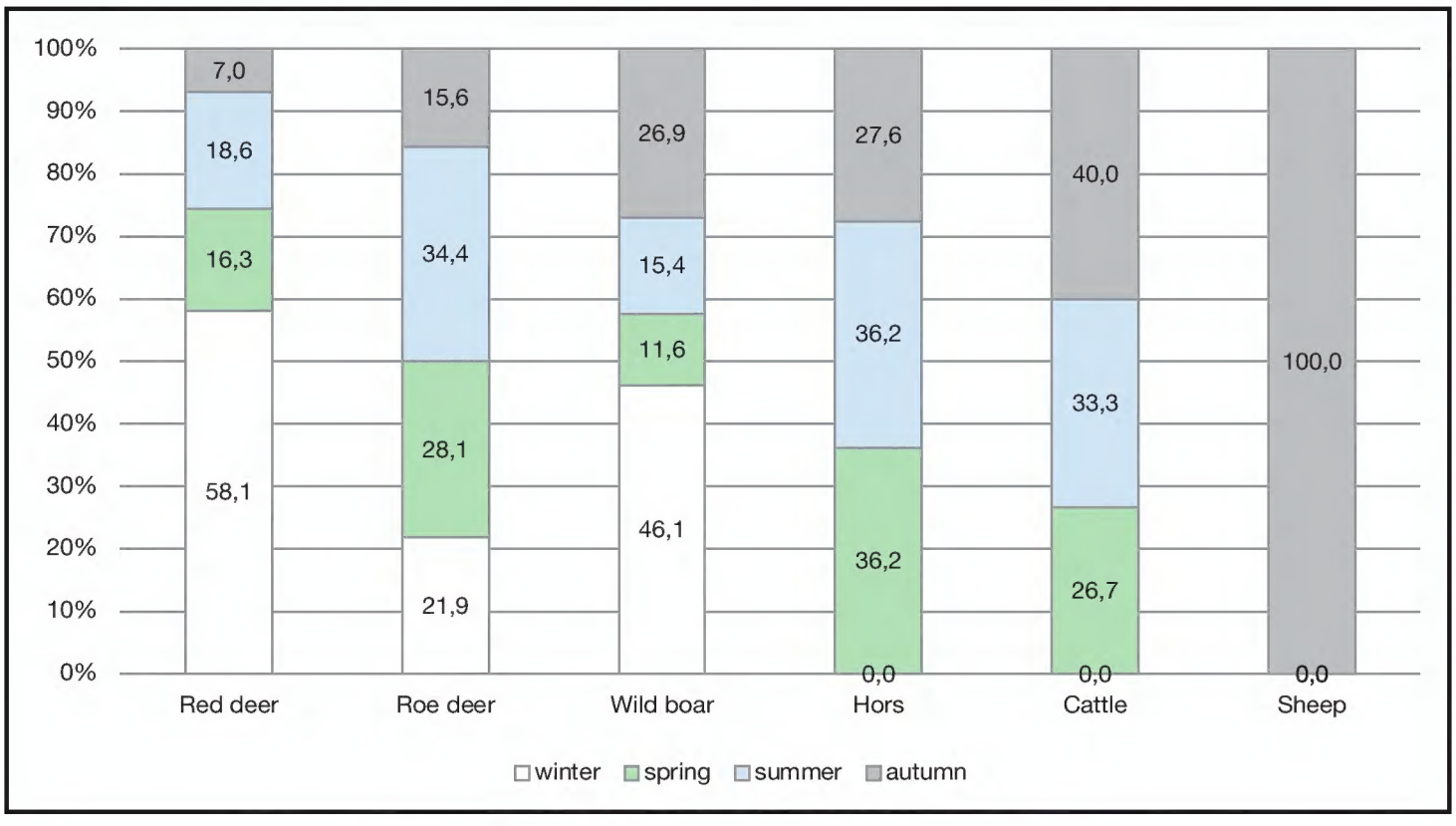



**Figure 3.** Seasonal prey distribution in Wolf diet.

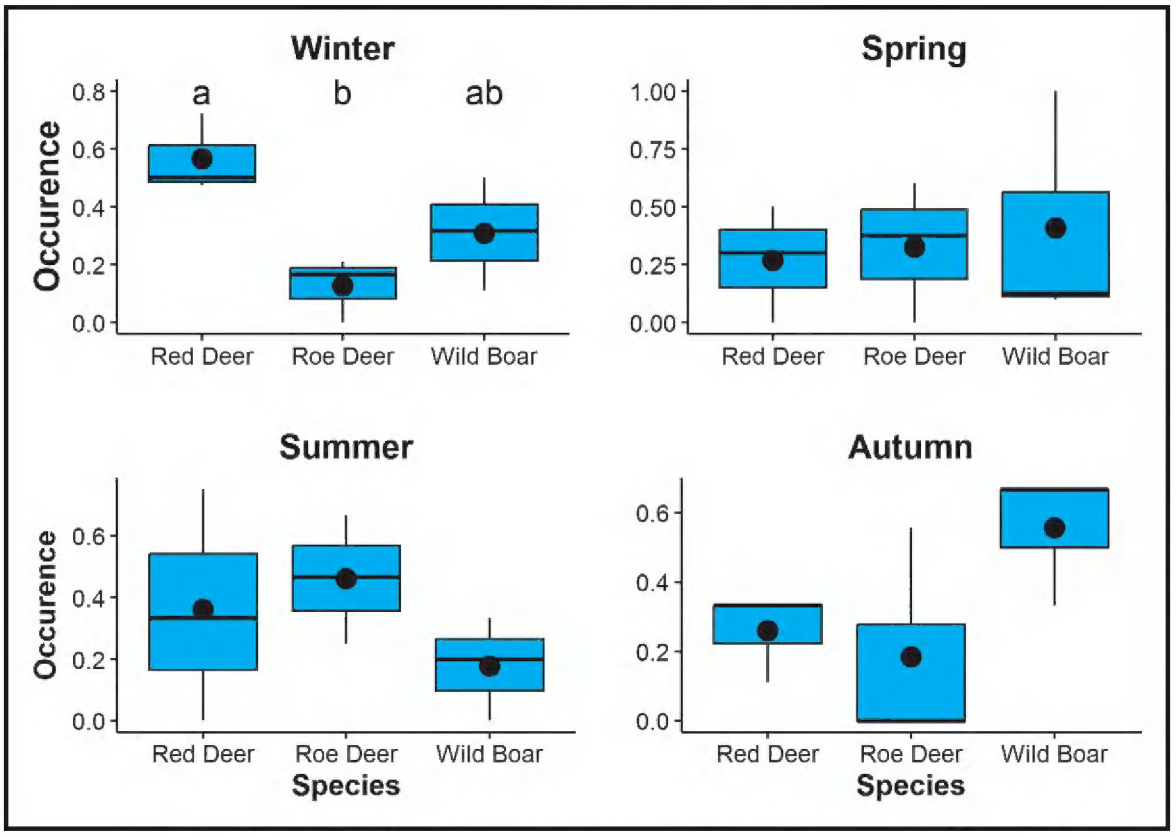
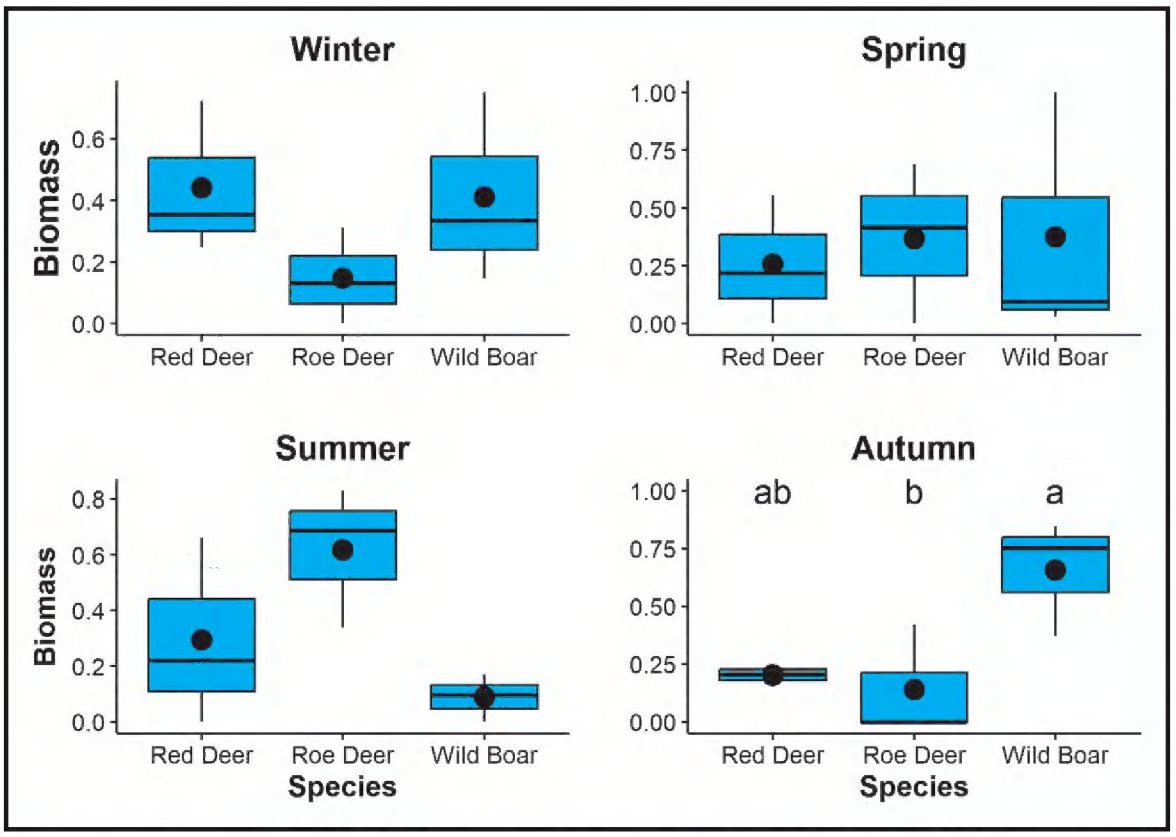



**Figure 4.** Proportions of wild prey according to occurrence by seasons. Groups of means, indicated with different letters are significantly different at $P < 0.05$ according to Tukey post-hoc test. Mean values are shown with black dots, medians with – lines, 25% and 75% quartiles – with boxes, minimum and maximum – with whiskers.

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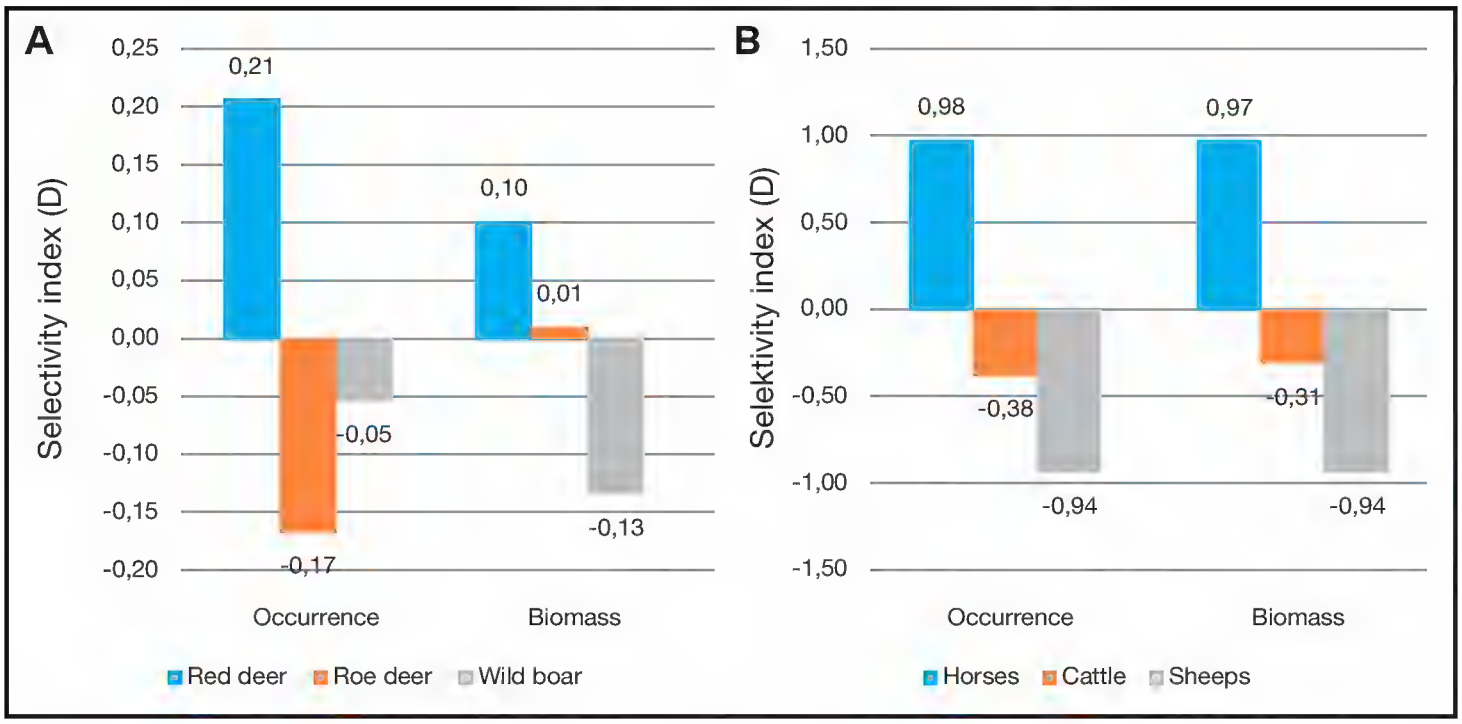


**Figure 6.** Wolf selectivity index in the Central Balkan Mts. according to the occurrence of prey species in excrements and according to their biomass: **A** to ungulate game (total for all seasons); **B** to livestock.

in respect of occurrence ($D$ = -0.17) and biomass ($D$ = 0.01). For Wild Boar the coefficient shows negative values, but not by much for both indexes (-0.05) and (-0.13) (Fig. 6A).

Occurrence of prey in scat samples shows a rising use of Red Deer in winter ($D$ = 0.30) (Fig. 7A). Roe Deer's selection is negative ($D$ = -0.44), while Wild Boar despite its positive selection ($D$ = 0.1) cannot be said to be a preferred Wolf's prey. During the summer period, the Red Deer coefficient is close to zero ($D$ = 0.07). For

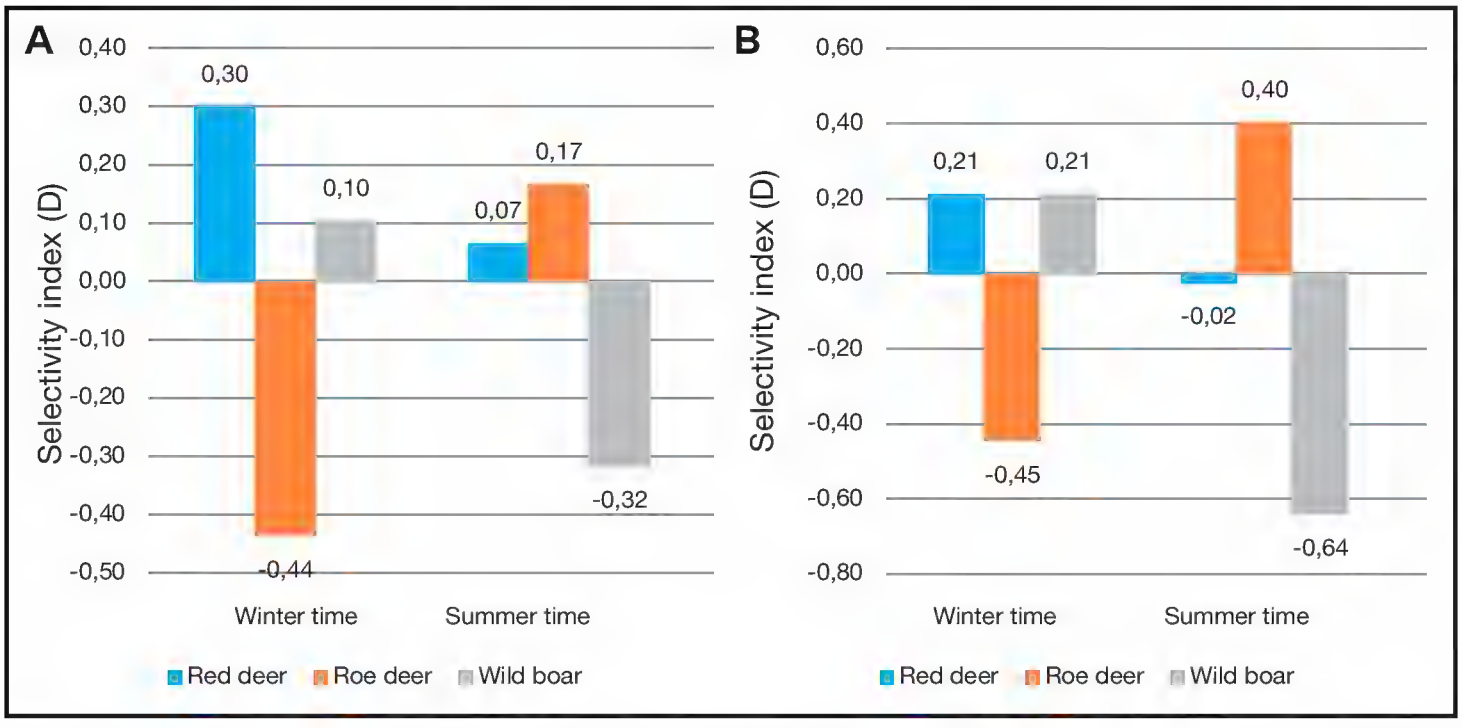


**Figure 7.** Wolf selectivity index for wild ungulates in the Central Balkan Mts. in summer and winter according to occurrence **A** and biomass **B** of prey in excrements.

Roe Deer it acquires a positive value ($D = 0.17$). During the warm period of the year, Wild Boar is not a preferred prey ($D = -0.32$) (Fig. 7A).

In winter, prey biomass is of equal positive value for Red Deer and Wild Boar ($D = 0.21$), and again with negative selection for Roe Deer ($D = -0.45$). The warm period of the year shows negative selection for Red Deer ($D = -0.02$), positive selection for Roe Deer ($D = 0.40$), and negative selection for Wild Boar ($D = -0.64$) (Fig. 7B).

Wolf selectivity in respect of livestock shows a clear preference for Horses in both indexes. For frequency of occurrence, it is $D = 0.98$ and for biomass use $D = 0.97$. Big livestock shows negative selection for both indexes (-0.38) and (-0.31). Sheep are avoided by the carnivore, with the coefficient showing considerable negative selection ($D = -0.94$), equal for both indexes. (Fig. 6B).

As noted, 23 wolves live on the studied area, from which it follows that 25185.0 kg of meat per year is needed to feed the predator (Table 6). Taking into account the percentage of biomass in individual victims measured for each excrement sample and knowing the total biomass needed by wolves in the area, it was calculated that the most biomass for their nutrition falls on the Roe Deer (5025.78 kg) and the least on the wild Boar (2870.01). In livestock, Horses have the largest share (9474.31), and Sheep have the smallest share (715.56) (Table 6).

Taking into account the average live weights of individual types of victims, it is calculated that this is equal to 68.3 Red Deer, 279.2 Roe Deer, 63.8 wild Boar, 118.4 Horses, 29.8 Cattle, 13.0 Sheep (Table 6).

**Table 6.** Relative participation of biomass and number of victims in the diet of the Wolfs in the studied area for one year.

| Species | Relative share (%) | Biomass (kg) | Average (kg) | Victims (number) |
|---|---|---|---|---|
| Red Deer | 18.71 | 4712.76 | 69 | 68.3 |
| Roe Deer | 19.96 | 5025.78 | 18 | 279.2 |
| Wild Boar | 11.40 | 2870.01 | 45 | 63.8 |
| Horses | 37.62 | 9474.31 | 80 | 118.4 |
| Cattle | 9.48 | 2386.58 | 80 | 29.8 |
| Sheep | 2.84 | 715.56 | 55 | 13.0 |
| total | 100.00 | 25185.0 | | |

## Discussion

*Wolf seasonal selectivity of basic prey*

The diet of the Wolf in its large area of habitation is extremely variable, but, in the main, it is represented by large ungulates (Kudaktin 1978; Pavlov 1982; Mech and Boitani 2004; Wagner et al. 2012; Fuller et al. 2003; Peterson and Ciuci 2003; Gazzola

et al. 2005; Bassi et al. 2012; Imbert et al. 2016; Jedrzejewski et al. 2002; Myslajek et al. 2022). The principal prey of the Wolf is not one and the same. It depends on a numbers of factors, such as: geographical specifics of a given area (including seasonal influences), occurrence of prey species, and their vulnerability (the latter according to the morphological specifics and ecology of a given prey animal), and also whether different species of ungulates are optimal prey for the carnivore (Gromov 1979; Rukovskiy 1985; Meriggi and Lovari 1996; Spassov et al. 2000; Zlatanova et al. 2014; Mech and Peterson 2003; Sand et al. 2008; Bibikov et al. 1985; Mech and Boitani 2003; Jedrzejewski et al. 1992; Mattioli et al. 2004; Nowak et al. 2005; Fritts et al. 2003; Dondina et al. 2015).

In Europe, Bulgaria included, the principal wild prey of the Wolf is associated with Wild Boar, Roe Deer, and Red Deer. Usually, according to research in Italy, Romania, Turkey, and Poland, the principal prey is Wild Boar (Mattioli et al. 1995, 2004; Sin et al. 2019; Mengüllüoğlu et al. 2019; Octenjak et al. 2020; Myslajek et al. 2022; Dolapchiev et al. 2022). In a lesser way and by data from Germany and Poland, it is associated with Roe Deer (Valdmann et al. 1998; Nowak et al. 2005; Myslajek et al. 2022). According to data from Germany and Bulgaria, Red Deer is least common as prey (Ansorge et al. 2006; Koychev and Uzunowa 2023). It is to be stressed however, that seasonal dependence for selection of prey is noted in all publications. At the same time, data for preference for one or another type of prey show considerable differences relative to the surrounding conditions (presence of the various prey species, numbers of prey animals, environmental conditions, etc.). The pronounced plasticity of the carnivore against this background is to be emphasised.

The fact that the Wolf's main prey in the Central Balkan Mts. is related to wild and domestic ungulates creates a certain conflict between the predator and hunting managers, as well as livestock owners, despite the fact that a national park exists in the studied territory.

*Red Deer in Wolf's diet in the Central Balkan Mts.*

In winter, Wolf's dietary needs in the Northern part of the Central Balkan Mts. are predominantly satisfied by Red Deer. The percentage of its presence in Wolf excrements is the highest (56.8%). Red Deer comes second in Wolf's diet in spring and summer. One of the main reasons for its importance as prey is the advantageous proportion between its biomass and vulnerability (Spassov et al. 2000) additionally allowing repeated intake of 'leftover' food (Schmidt and Mech 1997). Concerning winter, its importance for Wolf's diet comes also from the greater vulnerability of Red Deer due to a more effective hunting by family packs (Jedrzejewski et al. 2002). The presence of Red Deer in the predator's diet reaches up to 81–91% in other regions of the species area of distribution (Potvin et al. 1988; Spaulding et al. 1998). In the Sikhote-Alin Reserve in the Far East, the Wolf shows preference for Izubr (*Cervus canadensis xanthopygus* H. Milne-Edwards, 1868), which is explained by the fact that compared to Moose and Wild Boar, it is the more accessible prey (Gromov 1979).

In respect of Red Deer, the Wolf of the Central Balkan Mts. shows positive selection also as regards Ivlev's selectivity index ($D$ = 0.30 for occurrence, and $D$ = 0.21 for biomass). In Białowieża Forest, the selectivity index shows even greater preference for Red Deer with a value of 0.58 (Jedrzejewski et al. 2002). However, according to other data from Central and Western Poland the index is negative (-0.03) (Nowak et al. 2011).

Irrespective of the fact that the taxation of the game is done once a year (spring time), $p$ for the Red Deer (and also for the Roe Deer) does not change from spring to autumn, regardless of the newborns in the spring. In the wild Boar $p$ increases due to the greater number of newborns. This would further confirm the value of $D$ for the Red Deer.

*Roe Deer in Wolf's diet in* the *Central Balkan Mts.*

According to our research, in spring and summer, Roe Deer ranks first among wild ungulates: (20.8%) and (18.8%). In autumn, it ranks second, and third during the winter. Data from the Western Rhodopes are similar. There Roe Deer is ranked first in summer (46.3%), while in autumn it comes again second (Serafimov et al. 2008). When calves begin to accompany their mothers (late spring–early summer), they acquire the mothers' smell and become highly vulnerable. Both the mother and the not fully grown calf are easy to be detected and tracked by Wolves. Possibly, this may explain the high occurrence of calves in the diet of Wolves in late spring – early summer. A possible reason for the weak presence of the species in the carnivore's diet during the winter could be explained by the biomass of the animal, which can satisfy the dietary needs of no more than three wolves (Wagner et al. 2012). According to the selectivity index for Roe Deer in the Central Balkan Mts., the species is a preferred prey in spring and summer (particularly according to biomass in excrements) (see Fig. 7B). At the same time, the average index value suggests lack of preference for Roe Deer, which is more or less the same as the situation in Białowieża Forest ($D$ = -0.36) (Jedrzejewski et al. 2002). Considerably higher (positive) is the index average for Italy, for the period 1993–2000 ($D$ = 0.67) (Mattioli et al. 2004), as well as in Germany ($D$ = 0.32) (Ansorge et al. 2006).

*Wild Boar in Wolf's diet in the Central Balkan Mts.*

Wild Boar's place in Wolf's diet ranks, as percentage, first in autumn, compared to the other principal prey species – Red Deer and Roe Deer. Wild Boar's place as prey comes second during the winter, and last in spring and summer (Fig. 3). Overall data shows Ivlev's index to be negative. For occurrence it is $D$ = -0.05 and for biomass $D$ = -0.13 according to the data of official taxation. Wolf positive selection occurs only in winter ($D$ = 0.21). It is most probably due to the forming of big Wild Boar herds, which contributes to the survival of the population, while, at the same time, makes the herds easily detected. Side by side with this, in winter Wolves hunt in packs which makes predation more effective. Depending on varying conditions and types of relations with the prey, selectivity in respect of this species varies, as well as to

others. Seasonal differences in Wolf's use of Wild Boar can be also connected with the presence of a bigger juvenile cohort in spring, and to that of not fully grown piglets in winter (Wagner et al. 2012 Myslajek et al. 2022). (This type of seasonal selection thus targets predominantly young and not fully developed animals, while adult males would be avoided due to risk of injuries). It is probably for this reason that frequency of occurrence of Wild Boar in winter in the Central Balkan Mts. is the highest, as well as in Hunting Farm Beglika in the Western Rhodopes (30.2%) (Serafimov et al. 2008). Genov et al. (2008) claim Wolf preference for Wild Boar in the same region to be the highest in total terms (as percentage of established food). Wolf selectivity in Osogovo, where Red Deer is next to absent, also shows preference for Wild Boar (Ivlev's coefficient varies between 0.54 and 0.83) despite the fact that Wild Boar density is smaller than that of Roe Deer by a factor of 10 (Dolapchiev et al. 2022), being highest in autumn. It is also the most preferred prey in Tuscany (Stahlberg et al. 2017). In the Southeastern Romanian Carpathians, Wild Boar is similarly the most frequent kind of prey in the diet (72% for biomass), as well as the most preferred by the carnivore ($D = 0.74$) (Sin et al. 2019). In Estonia its preference is positive ($D = 0.23$), while the attitude towards Roe Deer is neutral ($D = 0.07$) (Valdmann et al. 1998). In Southeastern Poland, Wolves have shown positive selection for Wild Boar in 2001–2002, similar to the winter one for the Central Balkan Mts. ($D = 0.21$). In 2017–2020 preference of Wild Boar was even more categorical ($D = 0.71$) (Myslajek et al. 2022). At the same time, it needs to be noted that in Southeastern Poland the preferred Wolf prey is a species not present in the Central Balkan Mts. – the European fallow Deer (*Dama dama* L.). Results for the Polish part of Białowieża Forest are opposite, showing ($D = -0.36$) for Wild Boar (Jedrzejewski et al. 2002). This finding is very similar to the data for the Central Balkan Mts. for all seasons except winter.

*Seasonal differences concerning livestock*

The way livestock is bred and the degree to which it is protected determines their share in Wolf diet (Pavlov 1982; Bibikov 1985; Llaneza et al. 2000; Fritts et al. 2003; Mech et al. 2003; Bradley and Pletscher 2005; Iliopoulos et al. 2009; Dondina et al. 2015). The great numbers of livestock herds in Central Balkan Mts., combined with inefficient protection, or even the lack of such, facilitate easy accessibility of the Wolf to its prey, from the end of spring till the beginning of autumn. In this season, the wild ungulates are distributed more evenly over the territory, being engaged in calving and rearing their young. This makes detecting and catching them more difficult, in addition to wolves' packs being less numerous, which, in turn, makes rounding up prey more difficult. In winter, the situation is radically different due to livestock being penned up in or close to settlements. Consequently, Wolves rely for food principally on wild ungulates in such regions. Attacking livestock occurs predominantly in the summer months. Data in the literature attributes 83% of all livestock losses to be happening in the months May to September (Fritts et al. 2003). The taking out for grazing of 3-month-old calves has a pronounced effect on Wolf predation under this form of stock breeding, due to the heightened vulnerability of young calves (Bradley and

Pletscher 2005; Iliopoulos et al. 2009; Dondina et al. 2015). Horse is the predominant prey animal in the Central Balkan Mts. in spring and summer (mainly juveniles). Predation on Cows occurs in autumn, with that on Sheep only in autumn (Fig. 3). Due to their accessibility, newly born and young Horses constitute the bigger part of Wolf diet in the snow-free period of the year. The situation is analogous to that of Northern Portugal, where Wolves also show preference for freely grazing Horses on mountain pastures (Vos 2001). It is also similar to that of Central Asia (Altai), where Horse losses are close to three times those of Cows (Bondarev 1985). The main reason is to be seen in the practice of free grazing of Horse herds which are let out to freely graze already in spring, and subsequently give birth to their young without any protection, or being taken in at night. The small share of Cows predated on by Wolves is to be seen, on the one hand, in the greater numbers of Horses, and on the other in their being more difficult prey. Cows are associated with a greater degree of socialization and mutual defense, the majority of herds being guarded by Cow herds and dogs and, as a rule, the majority of them being taken in at night. Sheep are the only kind of domestic animal which cannot dispense with human protection in the presence of Wolves. While they represent the easiest prey for Wolves, their share in the Wolf's diet in the Central Balkan Mts. is small. The reason for that is that they are not left without human attendance neither during daytime, nor at night. Wolf attacks predominantly occur in late summer and early autumn (usually in September), when Wolves form packs and the hunting training of the young begins (Spassov 2007).

## Conclusions

Data for Wolf preference for one or another prey type show considerable seasonality, as well as pronounced differences according to habitat conditions. This is true for Central Balkan Mts. and is consonant with other research from the Wolf's extensive area of habitation. It also speaks of the pronounced adaptability of the carnivore in terms of prey selectivity.

In the Central Balkan Mts. the Wolf's basic diet consists of domestic and wild ungulates, with their respective part varying considerably according to season.

In the warm period of the year, numerous livestock herds in combination with inefficient protection, or even without any such, ensure easy access to this prey type in Central Balkan Mts. This holds true from the end of spring to the beginning of autumn. From all prey animals, the biggest share goes to juvenile Horses. These conclusions should help to more effectively protect the livestock during the warm period of the year on the studied territory.

During the winter, the Wolf relies primarily on the big game in the region: Red Deer, Wild Boar, and Roe Deer.

Red Deer is the commonest prey animal in winter, judging by its percentage of occurrence in the predator's excrements. Despite the fact that Ivlev's coefficient does not show categorical preference for any of the three prey species for all seasons, it

can be claimed that in winter Red Deer is the preferred prey for the region of the Central Balkan Mts. ($D = 0.3$).

In spring as in summer, Roe Deer ranks first among the wild ungulates according to the percentage of occurrence in the predator's diet.

The part of Wild Boar in Wolf diet in the Central Balkan Mts. places it first in the autumn, in percentage terms, compared to the other two principal prey species (Red Deer and Roe Deer).

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